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PARTICULARS OF CERAMIC ARTICLE FABRICATION BY IMPACT PRESSING

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A new technology for fabricating ceramic articles (bricks, tiles, and others) is described. This technology shortens the production cycle by intensifying the processes occurring during pressing and firing, which makes it possible to obtain ceramic articles with enhanced mechanical strength (45 – 60 MPa) and improved appearance and quality. The processing regimes chosen are validated.

Key words: ceramic article, mechanical strength, pressing, explosion, shock wave.

Modern technologies for manufacturing ceramic articles used in home construction and paving roads are very labor-intensive and time-consuming. The common technologies include the following: preparation of a clay body, which involves coarse milling of the initial material, drying, fine milling, sieving of large inclusions, mixing with additives and wetting; compaction of loose powder bodies with moisture content 8 – 12% under pressure 15 – 40 MPa in hydraulic presses; drying of the green part in conveyer and tunnel dryers for 8 – 24 h and firing. Articles are fired at temperatures 920 – 1200°C in tunnel furnaces for 40 – 80 h [1]. Such a technology is very time-consuming, requires considerable equipment and many operators, and it is difficult to obtained ceramic articles of high quality.

During pressing air bubbles are present between and inside large inclusions of the initial raw material. During firing these bubbles expand and, escaping to the outside, often result in the formation not only of microcracks but also quite large cracks, reducing their mechanical strength and degrading the appearance and, correspondingly, the quality of the ceramic articles.

The technology proposed in [2] for manufacturing ceramic articles makes it possible to significantly shorten the production cycle by the elimination of a number of operations, which became possible owing to the intensification of the processes occurring during pressing and firing. This makes it possible to obtain ceramic articles with high mechanical strength, improved appearance and, correspondingly, higher quality.

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The new technology for manufacturing ceramic articles includes drying of clay, preparation of the body and pressing articles followed by firing. In addition, the drying is performed for 2 – 4 h at 30 – 40°C. The product obtained is comminuted to particle size 0.3 – 0.5 mm, pressed by a shock wave in an electrohydrodynamic press under pressure 800 MPa, and then heated to the firing temperature at a rate 1 – 4 K/min.

Drying at 30 – 40°C for 2 – 4 h is necessary in order to impart minimal plastic properties to the initial material, making possible the subsequent comminution of large particles without sticking on the working parts of the crushers.

The crushing of the product to particle size 0.3 – 0.5 mm is necessary in order to create a uniform, finely disperse body uniformly distributed over the entire volume of the article and ensuring the minimal initial porosity when filling the die.

It is well-known [3, 4] that in order to obtain a strong bond between materials in the solid state a certain degree of activation of the atoms of the surfaces being joined is required. This is attained by introducing into the joining zone a definite amount of heat (thermal activation), energy of elastoplastic deformation (mechanical activation) and so on. Ordinary static pressing does not give adequate activation of atoms for this purpose and for this reason impulse impact pressing was used as the new technology to obtain ceramic construction materials. In an electrohydrodynamic press, where the prepared ceramic mixture is pressed, a shock wave forms when the electrodes are short-circuited in water, i.e., an explosion occurs in a closed chamber. The explosion is a process of very rapid (10^{-5} – 10^{-7} sec) physical or chemical transformation of the system, in which potential energy is converted into mechanical work [5].

The products of the explosion are ionized particles of high-energy plasma flying apart at speeds of several kilometers per second; these particles are followed by disperse particles of the pressed material. In addition, the plasma cleans the surface, removing the films covering the surface of the solid particles.

The pressures developed as a result of the explosion make it possible to accelerate the die forming the required part (brick, plate, tile and others) in the die-casting mold up to high speeds. When the die collides with the surface of the loaded material a shock wave is excited in the material and propagates into it. During this process the volume of the body in front of the wave is completely stress-free and the material behind the shock front is compressed. The boundary between these states is the shock front, moving with a velocity of several kilometers per second. In powder media the compression occurs within $10^{-5} – 10^{-7}$ sec. For such short loading times very high normal and tangential stresses arise, giving rise to extremely high rates of deformation of the material with practically complete absence of heat exchange with the surrounding medium. The pressure increase in the shock front has the greatest effect on the increase of the density of the final ceramic article. Since there are fewer particles per unit mass in the coarse-grain than in fine-grain powder, each grain is subjected to a large part of the pressure, and this pressure will do a large amount of the work of dispersing the pressed particles.

In this connection, as the pressure of the shock wave increases, the number of pores will decrease because they become filled with small particles and the volume of the initial ceramic mixture will be compacted. For this reason, the pressing by the shock wave with pressure 800 MPa contributes significant energy to the crystal lattice of the clay particles, which activates the surface interaction forces along the contact surfaces of the particles and, in consequence, in the creation of a non-porous monolithic strong ceramic article.

Heating to the firing temperature at the rate 1 – 4 K/min ensures uniformity of diffusion processes and adhesion interaction along contact surfaces of clay particles and makes it possible to avoid internal stresses, which can appear at higher rates of heating because of the nonuniform distribution of the heat flux over the entire volume of the article.

Investigations designed to determine the physical and mechanical properties of ceramic articles by the procedure described in [6] established that the ultimate strength in compression of samples obtained by the proposed new technology is 45 – 60 MPa, while the ultimate strength in compression of samples obtained by the technology of [1] is 15 – 20 MPa, which attests to a large increase in the quality of the ceramic articles obtained by the new technology [2].

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